FEATURED PROJECT

SMART EXPERIMENTAL DESIGNS PROVIDE MILITARY DECISION-MAKERS WITH NEW INSIGHTS FROM AGENT-BASED SIMULATIONS

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Professor Susan M. Sanchez, Department of Operations Research and the Graduate School of Business and Public Policy

> "Imagination is more important than knowledge. Knowledge is limited. Imagination encircles the world."
> **Albert Einstein**

The 6th International Project Albert Workshop, described elsewhere in this newsletter, is part of an ongoing effort that seeks to exploit the advances in computing power and new technologies in order to "provide quantitative answers…to important questions facing military decision-makers" (Brandstein, 1999). In particular, in his former position as Chief Scientist of the U.S. Marine Corps, Dr. Brandstein was frustrated with legacy models because he felt they were unable to support analysis needs in the rapidly evolving global environment. Areas of particular concern were, and continue to be, our inabilities to adequately deal with the chaos inherent in military engagements, the human dimensions of warfare (e.g., leadership, courage, trust, unit cohesiveness), and adversaries who adapt their behavior based on perceptions of

--continued on page 21

About the INVESTIGATORS

Thomas W. Lucas is an Associate Professor in the Department of Operations Research (OR). Dr. Lucas received a B.S. in Industrial Engineering and Operations Research from Cornell University, an M.S. in Statistics from Michigan State University, and a Ph.D. in Statistics from the University of California at Riverside. He joined the NPS faculty in 1998, and has been teaching courses in statistics and combat modeling. He was recognized by the OR Department for his Outstanding Instructional Performance in 1999.

Thomas W. Lucas

Dr. Lucas is a member of the American Statistical Association, the Military Applications Society of the Institute for Operations Research and the Management Sciences (INFORMS), and the Military Operations Research Society (MORS). His primary research interests are combat analysis, design of simulation experiments, and robust Bayesian statistics. Previously, he worked as a statistician at RAND and as a systems engineer at Hughes Aircraft Company.

Susan M. Sanchez is a Professor and Associate Chair of Instruction in the Department of Operations Research. She also holds a joint appointment in the Graduate School of Business and Public Policy. Dr. Sanchez received a B.S. in Industrial and Operations Engineering from the University of Michigan, and her M.S. and Ph.D. in Operations Research from Cornell University.

Susan M. Sanchez

Dr. Sanchez came to NPS as a Senior Postdoctoral Associate under a National Research Council fellowship in 1999, and joined the NPS faculty in 2000. She teaches courses in statistics, operations research, and simulation analysis.

Dr. Sanchez is a member of the Institute for Operations Research and the Management Sciences (INFORMS), the American Statistical Association, and the American Society for Quality. She is currently President of the INFORMS College on Simulation, and is also President of the INFORMS Forum on Women in Operations Research and Management Science. She serves as Simulation Area Editor for the *INFORMS Journal on Computing* and as an Associate Editor for *Naval Research Logistics.* Her research interests include the design and analysis of simulation experiments, selection procedures, and active learning.

SMART EXPERIMENTAL DESIGNS, *continued from page 20*

our strategies and tactics.

Project Albert focuses on *Operational Synthesis*—that is, the process of combining the information gleaned from a family of diverse analytical tools to provide the most compelling analyses. The majority of Project Albert's efforts have involved the building of relatively simple models, along with data farming and visualization environments in which they can be explored. These models by design are fast-running, flexible, and easy to use. They contain only the essence of a given question or scenario and utilize only that detail absolutely necessary to capture the relevant aspects.

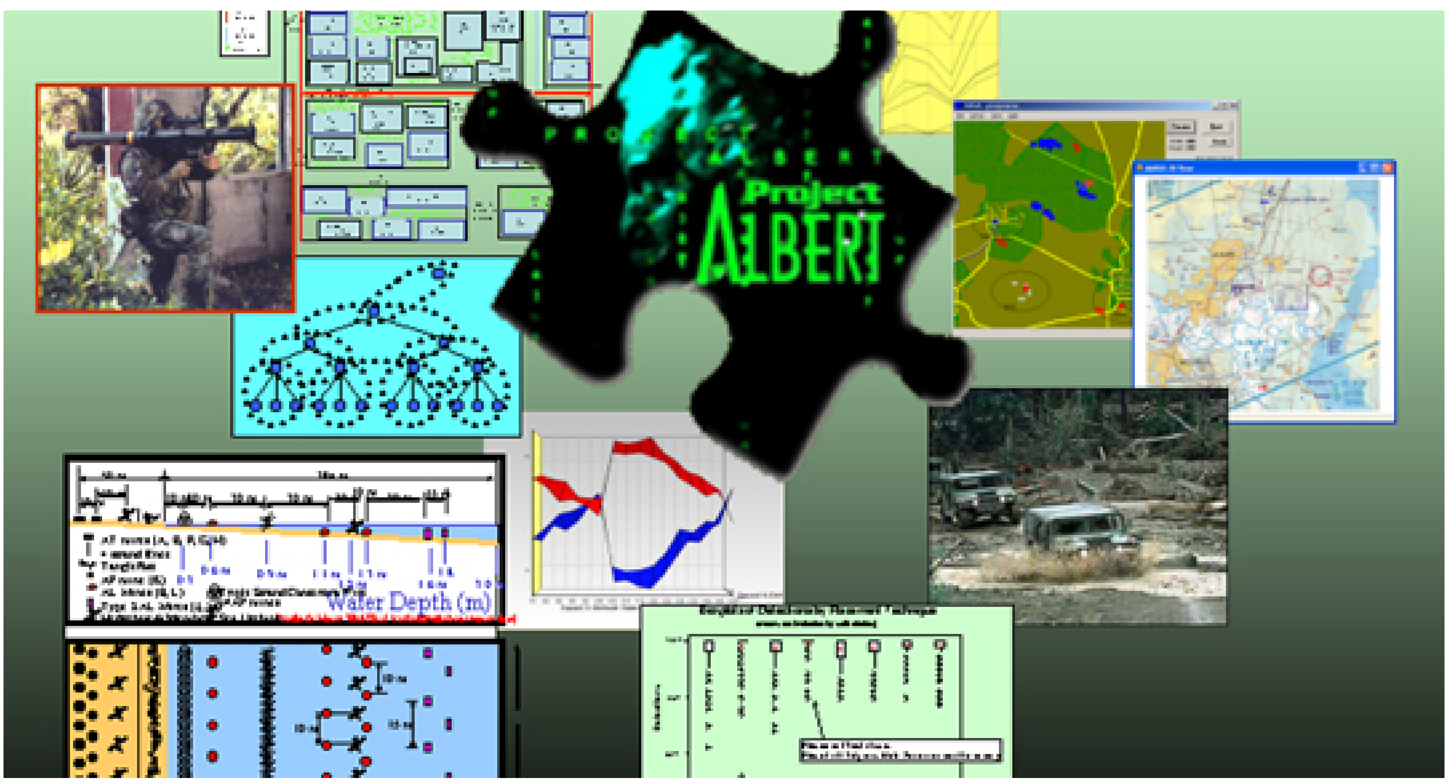
In order to fully evaluate all of the combinations of a model containing only 100 factors, each with only two settings, 2^{100} (about 10^{30}) runs of the model are necessary. Is this feasible? Former Air Force Major General Jasper Welch succinctly summarized the analyst's dilemma by the phrase "10^{30} is forever." Using a computer that can evaluate a model run in a nanosecond, an analyst who started making runs at the dawn of the universe would just be finishing his runs -- hence it would have taken him or her "forever" to explore the model.

To date, several modeling platforms have been developed by a diverse set of researchers under the Project Albert umbrella. Most of these are *agent-based simulations*. While the definition varies, we use this term to mean a simulation composed of agents, objects, or entities that make decisions (where to go, whom to shoot at, etc.) autonomously. These agents are aware of, and interact with, their local environment through relatively simple internal decision rules. The rules determine an agent's "personality" traits, such as their drive to move toward or away from a destination, and alive or injured friendly (or enemy) agents. Additionally, group characteristics can be defined which affect group behavior—such as the difference in forces required for an agent in a unit to want to advance toward an enemy. An agent's physical characteristics include their ability to sense, communicate, and engage with other agents.

Motivation

While Project Albert's distillations are quite simple by traditional Department of Defense (DoD) simulation standards, they nonetheless contain many variables that an analyst might desire to explore. Thus, a key thrust of the project is to utilize supercomputing to "farm" or run the models many times—millions of computation experiments are

--continued on page 57



FEATURED PROJECT

SMART EXPERIMENTAL DESIGNS, *continued from page 21*

often made on a given scenario. While millions of runs seem like a lot, the number of runs required to comprehensively explore even the simplest distillation can be astronomically large.

Most of our models have more than 100 factors, many of which are continuous or can take on a large number of discrete values. Our analyses are often further complicated by the uncertainty corresponding to many (if not most) of the factors. Therefore, even with super computers and "simple" models, we typically cannot use brute force searches on more than about 5-10 factors at a time. Moore's Law suggests that we will be able to extend this only by about two factors (through an increase of two orders of magnitude in processing power) each decade. Thus, if we want computational experiments that look broadly across these models, we need better designs. Our research objective is to develop search strategies that give DoD analysts flexibility in fitting models when exploring high-dimensional computer simulations in situations in which there is considerable *a priori* uncertainty about the shapes of the response surfaces. To this end, we are working with several NPS students to develop new search algorithms and assess their performance (analytically and empirically) over a broad set of models and scenarios.

In one sense, this need to examine many factors is an old problem. Situations we have chosen to explore via experimental designs have always been complicated. However, practical limitations (for physical experiments) and computational limitations (for simulation experiments) have forced decision-makers to focus on only a handful of factors at a time—those deemed the most important. We have found that this narrow window into a system's behavior can give rise to misleading results. Important factors or interactions may be ignored, or the results may be highly sensitive to a model input that was set arbitrarily. If the exploration of the model's behavior begins broadly, this reduces the likelihood of inap-

--continued on page 58

--continued from page 56

ability and Testability Group within Boeing Commercial Airplane Company to participate in presentations/seminars on software and systems reliability. The intention of the seminars is to bring the latest research and theory before Boeing's designers.

OPERATIONS RESEARCH

T.C. Barkdoll, **D.P. Gaver**, K.D. Glazebrook, **P.A. Jacobs**, and S. Posadas, "Suppression of Enemy Air Defenses (SEAD) as an Information Duel," *Naval Research Logistics*, No. 49, 2002.

THE MODELING AND SIMULATION INSTITUTE

Prof M. Zyda has been nominated for the 2003 World Technology Award for Information Technology - Software and the MOVES Institute has also been nominated in the "corporate category." The winners of these prestigious will be announced at the 2003 World Technology Awards and World Technology Summit in San Francisco, California on 24-25 June 2003.

PROMOTION AND AWARD OF TENURE FOR ACADEMIC YEAR 2003

Award of Tenure

Professor Leonard Ferrari
Department of Electrical and Computer Engineering

Professor Thomas Housel
Department of Information Science

Associate Professor Bret Michael
Department of Computer Science

Promotion to Professor

Professor Douglas Fouts
Department of Electrical and Computer Engineering

Professor David Jenn
Department of Electrical and Computer Engineering

Professor James Suchan
Graduate School of Business and Public Policy

Promotion to Research Associate Professor

Research Associate Professor Susan Hutchins
Department of Information Science

Research Associate Professor Haf Jonsson
Center for Interdisciplinary Remotely Piloted Aircraft Studies

Research Associate Professor Douglas Miller
Department of Meteorology

Research Associate Professor Robin Tokmakian
Department of Oceanography

CONGRATULATIONS!